IJLST

ISSN: 0974-5335
IJLST (2011), 4(3):14-18

Hair As Bioindicator Of Metal Pollution Due To Occupational Exposure To Metals

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ABSTRACT :
Hair has been used as diagnostic tool for assessing trace element concentration. Metal pollution in work environment can also be identified by using hair as biopsy materials. In the present investigation 120 head hair samples were collected personally from the workers of different sections of locomotive and roadways workshop. 20 subjects not exposed to metal pollution at their work environment were included as controls and other 100 subjects working in 10 different sections of workshops were included as sample subjects. All head hair samples collected were thoroughly washed using deionised water, nonionic detergent (Triton X-100) and acetone to remove external contamination and then digested using acid mixture of Nitric acid and Perchloric acid. Hair sample solutions were then analysed for the concentration of Lead, Cadmium, Chromium, Manganese, Iron, Nickel, Cobalt and Copper using Atomic Absorption Spectrophotometer Perkin Elmer Model-5000. The data thus obtained were given suitable statistical treatment for mean, standard deviation and test for significance using Student 't' test. Seven metals out of eight were significantly higher in hair of cupola man and diesel mechanic and six metals were significantly higher in hair of spring smith and fitter than those of controls.

Key Words: Occupational exposure, trace and toxic metals, hair, Atomic Absorption Spectrophotometer

INTRODUCTION :

The development of metallurgy, heavy engineering and various types of chemical industries has given rise to new and complex problem of health hazards both for workers and population in vicinity to such industries. The wide spread use of metal in locomotive and roadways workshops have resulted in enhancing occupational hazards. These metals enter in the body through inhalation, ingestion, absorption through exposed parts of the body and injection and starts accumulating in different fluids and tissues. Exposure to metals, if leads to accumulation of metals, may lead to various health hazards like neurological problems, respiratory problems, cancer and reproductive problems etc [1-5].

Biomonitoring of human biological samples (tissues and fluids) with respect to essential, therapeutic and toxic elements is gaining great importance. The effect of deficiency or excess of essential metals like iron, copper, manganese, cobalt, nickel, chromium etc. or toxic metals like lead, cadmium, mercury etc. at the ultra trace level on human health can be studied [6-7]. Various toxic and essential metals can interact by influencing each other's absorption, retention, distribution and bioavailability in the body [(8)]. Although human occupational and environmental exposure to metals quite often involves multiple elements, very few studies of human subjects have attempted to investigate the metal body burden on humans. Measurement of tissue burdens of pollutants can help in assessing the occurrence and to a certain degree, the extent of uptake of pollutants from the environment [9]. Goulle analyesd 32 trace and toxic elements in hair and concluded that that lead, cadmium, manganese, chromium, cobalt, nickel and copper are of clinical and forensic interest [10].

Biomonitoring of hair is performed to determine the concentration of different components in hair like nicotine, opiates, trace and toxic metals [11-14]. Hair is used as bioindicator in different fields of science such as Medicine, Forensic, Environmental and Archaeology [15]. Hair analysis for concentration of elements can be done by using Atomic Absorption Spectrophotometer (AAS), Proton-Induced X-Ray Emission Spectrometer (PIXE), Neutron Activation Analysis (NAA), Inductively Coupled Plasma Mass Spectrometer (IC-PMS), X-Ray Fluorescence Spectrometer (XRF) [16].

In the present study concentration of two toxic metals lead (Pb) and cadmium (Cd) and six trace metals nickel (Ni) copper (Cu), iron (Fe), cobalt (Co), chromium (Cr) and manganese (Mn) have been determined in hair of workers of locomotive and roadways workshop. Total 120 male subjects were included in the study, out of which 20 were controls who were not exposed to metals at their work place and remaining 100 subjects were exposed subjects of 10 different sections of workshops. Cupola man, boiler mechanic, spring smith, fitter, diesel mechanic, foundary attendant, moulder, junior CMA (Chief Machine Attendant), furnace man, hammer man were the 10 groups of exposed subjects.

Hair samples were collected from all subjects under study and information relevant with subjects was obtained from a questionnaire recommended by World Health Organization (W.H.O.). Hair samples were

ISSN: 0974-5335
IJLST (2011), 4(3):14-18

washed and digested and analysed using Atomic Absorption Spectrophotometer Perkin Elmer Model-5000.

It was hypothesized that subjects under study are exposed to metal pollution at their workplace and these metals accumulate in their body. It was also hypothesized that workers of different sections are exposed to different metals at there work place. It was also goal of this study to determine the relation, if any, between trace (Cu, Co, Mn, Cr, Fe and Ni) and toxic metal (Pb and Cd) concentration in hair as all the metals under this study are heavy metals. The main aim of this study was to identify the population at risk to exposure to metals in occupational environment.

MATERIALS AND METHODS

Selection of site for possible metal exposure in locomotive and roadways workshops was carried out to identify the subjects and controls for the present study. 120 male subjects were included in this study, out of which 20 were controls, which are not exposed to metals at their workplace, they were office workers of workshops. 100 subjects working in 10 different sections of workshop viz cupola man, boiler mechanic, spring smith, fitter, diesel mechanic, foundary attendant, moulder, junior CMA, furnace man, hammer man and as such exposed to metals at there work place. Approximately 2 gm of head hair samples from nape region with 1 cm distance from scalp were collected using a stainless steel scissor and stored in airtight polythene. While sampling, other relevant information's of subject like age, sex, occupation was also obtained from a questionnaire recommended by World Health Organization (W.H.O.).

Hair samples were washed to remove external contamination with non-ionic detergent (Triton X-100), acetone and deionised water and kept for drying at 110^0 C for one hour in oven [17-18]. Approximately one gram of washed and dried samples were then digested using an acidic mixture of Nitric Acid and Perchloric Acid in 6:1 ratio in a fumehood chamber, until a colourless clear solution is obtained [19-20]. All chemicals used in washing and digestion of hair samples were of AR grade. The acid is now evaporated and white residue is then dissolved in 0.1 N Nitric Acid up to 50 ml.

The quantitative analysis of 8 metals under study viz. Pb, Cd, Ni, Cr, Mn, Fe, Co and Cu was performed with an Atomic Absorption Spectrophotometer (AAS) Model-5000 using air acetylene flame. The detection limit of instruments for Cd, Pb, and Mn was 2μg/ml, 20μg/ml and 3μg/ml respectively in aqueous solution and the detection limit for Cr, Fe, Co, Ni and Cu was 5μg/ml in aqueous solution. Separate cathode lamps were used for separate metals. Suitable statistical treatment was given to the obtained data to get mean, and test for significance was done using *student 't'* test.

RESULTS AND DISCUSSION

Head hair samples of all 120 subjects were analysed and results were obtained in μg/ml of solution which was then calculated and converted as μg/g. The minimum concentration of Cd, Pb, Cr, Mn, Fe, Co, Ni and Cu in hair was 0.02 μg/g, 2.73 μg/g, 0.03 μg/g, 0.01 μg/g, 18.2 μg/g, 0.00 μg/g, 0.07 μg/g and 0.58 μg/g respectively. The maximum concentration of Cd, Pb, Cr, Mn, Fe, Co, Ni and Cu in hair was 2.08 μg/g, 52.3 μg/g, 33.2 μg/g, 17.2 μg/g, 705 μg/g, 15.1 μg/g, 37.13 μg/g and 25.30 μg/g respectively.

Mean concentration of two toxic metals under study (Cd and Pb) and essential trace elements (Cr, Cu, Mn, Fe, Co and Ni) in hair of control workers and exposed workers of 10 different sections of workshops are given in Table 1. Mean value of metals in hair of control workers in was Cd 0.18 μg/g, Pb 7.53 μg/g, Cr 3.42 μg/g, Mn 5.84 μg/g, Fe 130 μg/g, Co 0.23 μg/g, Ni 4.48 μg/g and Cu 5.54 μg/g. On observing mean values of all metals in hair of controls it is found that the concentration of iron, which is one of the most essential trace metals in body, was highest where as concentration of cadmium which is a toxic metal was lowest.

The Cd level in hair in relation to type of occupation of workers were analysed and observed that, lowest mean concentration of cadmium was 0.05 μg/g, which was observed in hair of hammer man and highest mean concentration of cadmium was 0.61 μg/g in hair of cupola man which was approximately twelve times greater than that of hammer man and three times greater than controls.

Mean cadmium concentration in hair of workers all 10 sections was found higher as compared to controls. This difference was significant in cupola men, boiler mechanic, spring smith, fitter, diesel mechanic and foundary attendant, in remaining four categories there was no significant difference as compared to controls.

Lowest mean concentration of lead was 8.86 μg/g, which was observed in hair of furnace man and highest mean concentration of lead was 46.1 μg/g in hair of hammer man which was more than five times greater than that of furnace man and controls. Mean lead concentration in hair of workers all 10 sections were found higher as compared to controls. When compared with controls the lead concentration in hair was found significantly higher in workers of all section except furnace man.

IJLST

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Table 1. Mean Concentrations of cadmium, lead, chromium, manganese, iron cobalt nickel and copper in hair of Controls and Subjects exposed to these metals in workplace.

Subjects	n	Cd (µg/g)	Pb (µg/g)	Cr (µg/g)	Mn (µg/g)	Fe (µg/g)	Co (µg/g)	Ni (µg/g)	Cu (µg/g)
Controls	20	0.18	7.53	3.42	5.84	130	0.23	4.48	5.54
Cupola Man	10	0.61*	17.8*	5.25*	8.43	427*	1.00*	21.5*	18.3*
Boiler Mechanic	10	0.39*	12.7*	6.81*	2.67	127	0.54*	2.75	14.1*
Spring Smith	10	0.34*	14.2*	5.47*	2.76	95.7	0.66*	15.9*	14.8*
Fitter	10	0.30*	20.1*	6.61*	5.34	179	2.16*	9.30*	14.3*
Diesel Mechanic	10	0.30*	21.0*	4.77*	9.04	306*	0.43*	11.8*	13.4*
Foundary Attendant	10	0.28*	11.4*	2.24	0.97*	74.5	0.41*	6.76*	11.7*
Moulder	10	0.23	25.2*	3.71	7.35	265*	0.81*	6.12*	14.1*
Junior CMA	10	0.20	21.4*	1.88*	1.56*	104	0.33*	9.18*	10.0*
Furnace Man	10	0.20	8.86	2.06	0.83*	90.1	0.50*	11.5*	7.15
Hammer Man	10	0.05	46.1*	1.31	0.73*	72.7	0.07*	0.85*	15.1*

*Significant difference (P<0.05) n : number of subjects

Mean chromium concentration was lowest in junior CMA was 1.88 µg/g and highest mean concentration of chromium was 6.81 µg/g in hair of boiler mechanic which was three times greater than that of Junior CMA and twice than that of controls. Mean chromium concentration in hair of workers of four sections viz foundary attendant, junior CMA, furnace man and hammer man was found lower as compared to controls, but these differences were significant only in junior CMA. Mean concentration of chromium in hair was found higher in cupola men, boiler mechanic, spring smith, fitter, diesel mechanic and moulder and this difference was significant in all except moulder.

Highest mean concentration of manganese was 9.04 µg/g in hair of diesel mechanic which was approximately ten times greater than that of lowest concentration 0.73 µg/g, which was observed in hair of hammer man and approximately twice than that of controls. Mean manganese concentration in hair of workers of seven sections viz boiler mechanic, spring smith, fitter, foundary attendant, junior CMA, furnace man and hammer man was found lower as compared to controls, but the difference was significant in foundary attendant, junior CMA, furnace man and hammer man. Mean concentration of manganese in hair was found higher in cupola men, diesel mechanic and moulder but this difference was not significant.

Lowest mean concentration of iron was 72.7 µg/g, which was observed in hair of hammer man and highest mean concentration of iron was 427 µg/g in hair of cupola man which was approximately six times greater than that of lowest concentration and approximately thrice than that of controls. Mean iron concentration in hair of workers of six sections viz boiler mechanic, spring smith, foundary attendant, junior CMA, furnace man and hammer man was found lower as compared to controls, but these differences were not significant in workers of any section. Mean concentration of iron in hair was found higher in cupola men, fitter, diesel mechanic and moulder but this difference was significant only in cupola men, diesel mechanic and moulder.

Mean cobalt concentration was lowest in hammer man was 0.07 µg/g and highest mean concentration of iron was 2.16 µg/g in hair of cupola man which was approximately thirty times greater than that of lowest concentration and approximately ten than that of controls. Mean cobalt concentration in hair of workers of one section viz hammer man was found lower as compared to controls, and this difference was significant. Mean concentration of cobalt in hair was found higher in workers of remaining nine sections and these values were significantly different from control values. It reveals that there was significant difference in cobalt concentration in hair of workers of all sections as compared with control values.

Lowest mean concentration of nickel was 0.85 µg/g, which was observed in hair of hammer man and highest mean concentration of nickel was 21.5 µg/g in hair of cupola man which was approximately twenty times greater than that of lowest concentration and approximately more five times greater than that of controls. Mean nickel concentration in hair of workers of two sections viz boiler mechanic and hammer man was found lower as compared to controls, but these differences were found significant only in case of hammer man. Mean concentration of nickel in hair was found significant higher in cupola men, spring smith, fitter, diesel mechanic, foundary attendant, moulder, junior CMA and furnace man.

Mean concentration of copper was lowest in furnace man was 7.15 µg/g and highest mean concentration of nickel was 18.3 µg/g in hair of cupola man which was approximately two times greater than that of lowest concentration and approximately thrice greater than that of controls. Mean copper concentration in hair of workers of one section viz furnace man was found lower as compared to controls, but these differences were not found significant. Mean concentration of copper in hair of workers of remaining nine sections was found significantly higher.

From above results and data tabulated in Table 1 it is clear that workers in different sections are exposed to

different metals. Significant difference in values of control workers and subjects workers indicate that the difference is not by chance but this is actual difference due to metal pollution in the work environment [21]. Higher values of metals in hair suggest that exposure to metals leads to accumulation of metals in body; this accumulation can easily be monitored by using hair as biopsy tissue. On observing data of Table 1 it can also be summarized that workers are exposed to different metals at different work place. In hair of cupola man concentration of 7 metals was found significantly higher in the same way in boiler mechanic 5, in spring smith 6, in fitter 6, in diesel mechanic 7, in foundary attendant 5, in moulder 5, in junior CMA 4, in furnace man 2, in hammer man 2 metals were significantly higher in hair as compared to control values.

These results evinces that metal concentration in hair is related with environment which is also supported by other workers [23-24]. As correlation coefficient was not calculated in the present study direct relation between toxic and trace metals cannot be determined. But lower values of Mn, CO, and Ni, in Hammer man evinces that higher concentration of Pb effects the concentration of Mn, Co and Ni which is also supported by reported works [16, 25].

CONCLUSION:

These results show that workers are exposed to both toxic as well as trace metals at their work place. This exposure has accumulated metals in the body, hair as one of the fastest growing tissues of body also accumulates these metals in them. Therefore hair is best suited for such type of study involving occupationally exposed workers. These metals alter the normal biochemical reactions of body and cause adverse health hazards. Important preventive measures are to be taken to protect workers from being exposed to metals at their work place.

REFERENCES:

[1] Horn M.C., L. King, J.O. Nriagu, L. Kobeissi, N. Hammoud, J. Awwad, A.A. Abu-Musa, A.B. Hannoun (2008) Occupational and environmental exposure to heavy metals: Risk factors for male infertility in Lebnon? Repro. Toxicol. 25**:** 203-212.

[2] Mehra R. (2002) Scalp hair as a biological marker for trace elements in hair, Poll. Res. 21 (3): 253-259.

[3] Quandt S.A., B.T. Jones, J.W. Talton, L.E. Whalley, L. Galvan, Q.M. Vallojas, J.G. Grzywacz, H. Chen, K.E. Pharr, S. Isom, T.A. Arcury (2010) Heavy metals exposure among Mexican farmworkers in Eastern North Carolina, Environ. Res. 110 (1)**:** 83-88.

[4] Pradhan J., R.S. Thakur, S.N. Das, J. Das, S.B. Rao (1998) Effect of aluminum smelters on health and vegetation, Asian J. Chem. 10 (1)**:** 1-13.

[5] Rushton L., P. Elliot (2003) Evaluating evidence on environmental health risks, British Med. Bull. 68: 113-128.

[6] Li Y., L. Yang, W. Wang, H. Li, J. Lu, X. Zoo (2011) Trace element concentrations in hair of healthy Chinese Centenarians, Sci. Tot. Environ. 409: 1385-1390.

[7] Mehra R., M. Juneja (2004) Biological monitoring of lead and cadmium in human hair and nail samples and their correlation with biopsy materials, age and exposure, Indian J. Biochem. Biophys. 41**:** 53-56.

[8] Pizent A., J. Jurosovic, S. Telisman (2003) Serum calcium, zinc and copper in relation to biomarkers of lead and cadmium in men, J. Trace. Elem. Med. and Biol. 17 (3): 199-205.

[9] Goulle J.-P., E. Saussereau, L. Mahieu, D. Bovige, S. Groenwant, C. Lacroix (2007) Fingernail ICP-MS multi-elementary determination. A useful biomarker of metal or metalloid exposure, T. Seattle, Washington.

[10] Goulle J.P., L. Mahieu, J. Castermant, N. Neveu, L. Bonneau, G. Laine, D. Bouige, C. Loeroix (2005) Metal and metalloid multi-elementary ICP-MS validation in whole blood, plasma, urine and hair reference values, Forensic Sci. Int. 153: 39-44.

[11] Pichini S., I. Altieri, M. Pellegrini, R. Pacifici, P. Zucearo (1999) Analysis of Opiates in human hair by high-performance liquid chromatography, J. Liquid. Chrom. Rel. Tech., 22 (6): 873-884.

[12] Feng Q., Y. Suzuki, A.A. Hisashige (1997) Trace element contents in hair of Residents from Harbin (China), Medan (Indonesia), and Tokushima (Japan), Biol. Trace. Elem. Res. 59: 75-86.

[13] Mehra R., M. Juneja (2005) Element in scalp hair and nails indicating metal body burden in polluted environment, J. Sci. Indus. Res. 64: 119-124.

[14] Zhang H., Z. Chai, H. Sun (2007) Human hair as a potential biomonitor for assessing persistent organic pollutants, Environ. Intrnl. 33**:** 685-693.

[15] Pozebon D., V.L. Dressler, A. Mautsch, J.S. Becker (2008) Monitoring of platinum in a single hair by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) after cisplatin treatment for cancer, Int. J. Mass. Spectrom. 272: 57-68.

[16] Sela H., Z. Karpas, M. Zoriy, C. Pickhardt J. S. Becker (2007) Biomonitoring of hair samples by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), Int. J. Mass. Spectrom. 261**:** 199-207.

[17] Mehra R., A.S. Thakur, S. Punia (2010) Accumulation of lead, cadmium, nickel, and copper in hair of people living near heavy traffic area, J. Indian Chem. Soc., 87: 751-755.

[18] Mehra R., A.S. Thakur, S. Bhalla (2010) Trace level analysis of chromium, manganese, cobalt and iron in human hair of people residing near heavy traffic area by biomonitoring, Intrnl. J. Pharma. Bio. Sci. 1(4)**:** 57-61

[19] Babu S.V., K.H. Reddy, Y. Lingappa (2009) Spectrophotometric determination of cobalt in biological samples using 2-acetylpyridine semicarbazone, J. Indian Chem. Soc. 86**:** 312-315.

[20] Mehra R., M. Juneja (2003). Variation of concentration of heavy metals, calcium and magnesium with sex as determined by atomic absorption spectrometry. Indian J. Environ. Hlth. 45: 317-324.

[21] Triger D.R., W. Crowe, M.J. Ellis, J.P. Herbert, C.E. McDonnell, B.B. Argent (1989) Trace element levels in the blood of workers in two steel works and a non-ferrous plant handling lead and cadmium compared with a non-exposed population, Sci. Tot. Environ. 78: 241-261.

[22] Wang T., J. Fu, Y. Wang, C. Liao, Y. Tao, G. Jiang (2009) Use of scalp hair as indicator of human exposure to heavy metals in an electronic waste recycling area, Environ. Poll. 157: 2445-2451.

[23] Banza C.L.N.B., T.S. Nawrot, V. Haufroid, S. Decree, T.P. Putter, E. Smolders, B.I. Kabyla, O.N. Luboya, A.N. Ilunga, A. Mwanza, B. Nemery (2009) High human exposure to cobalt and other metals in Katanga, a mining area of the Democratic Republic of Congo, Environ. Res. 109: 745-752.

[24] Were F.H., W. Njue, J. Murungi, R. Wanjau (2008) Use of human nails as bio-indicators of heavy metals environmental exposure among school age children in Kenya, Sci. Tot. Environ. 393: 376-384.

[25] Rodrigues J. L., B. L. Batista, J. A. Nunes, C. J. S. Passos, F.B. Jr (2008) Evaluation of the use of human hair for biomonitoring the deficiency of essential and exposure to toxic elements, Sci. Tot. Environ. 405: 370-376